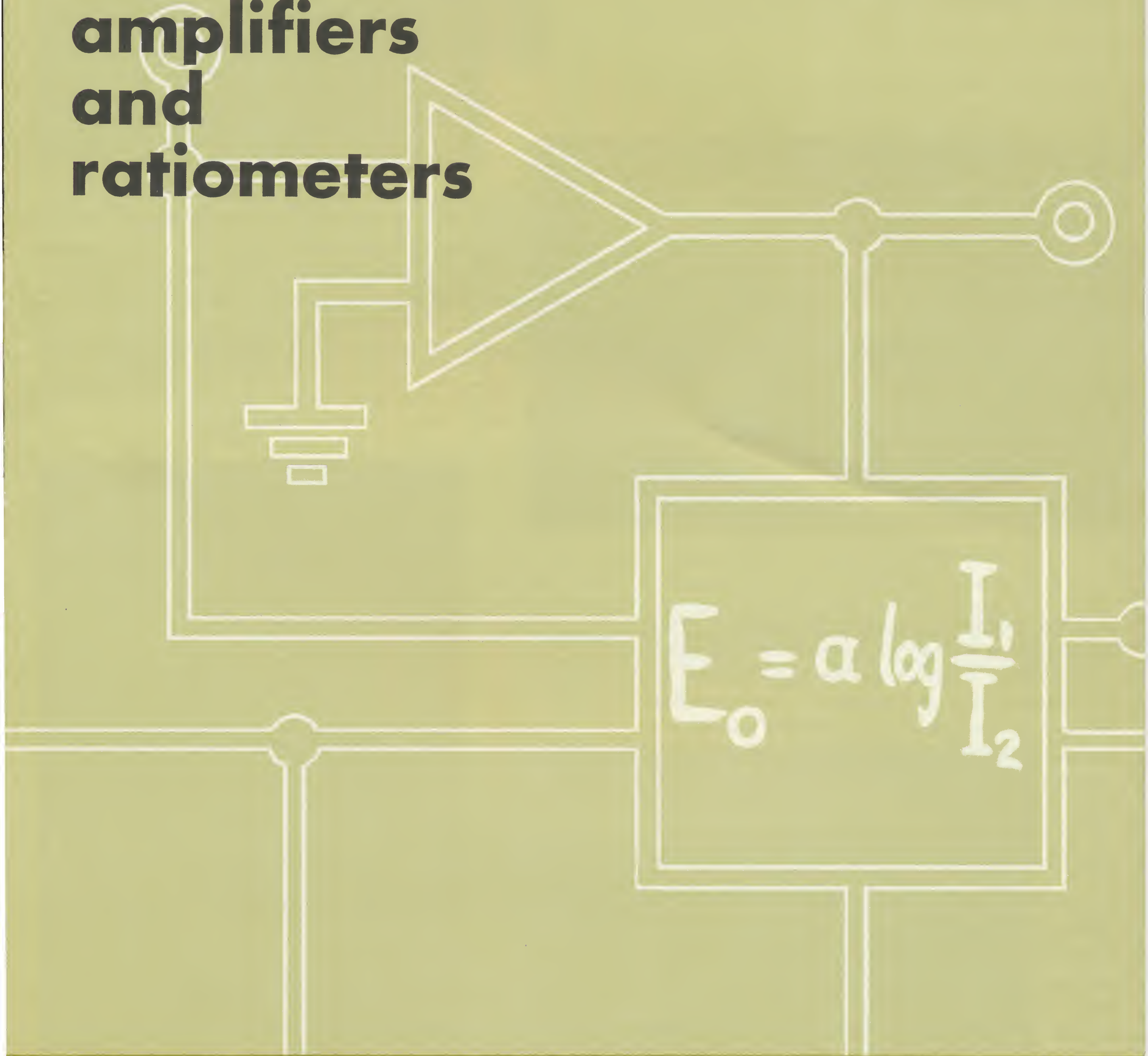
NEXUS

APPLICATION NOTE

APP. 12a. 2/64

logarithmic amplifiers and ratiometers



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An ideal silicon junction diode exhibits a forward current characteristic which varies exponentially with applied forward voltage, and is also dependent on junction temperature as shown in Figure 1a. Certain types of silicon planar transistors when diode connected are an excellent approximation to ideal diodes since their leakage currents and extrinsic resistances are extremely low.

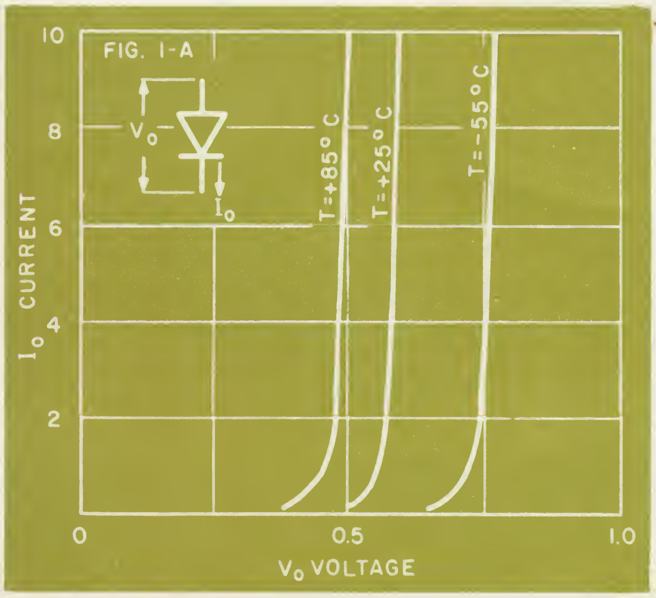

FIG. 1-A

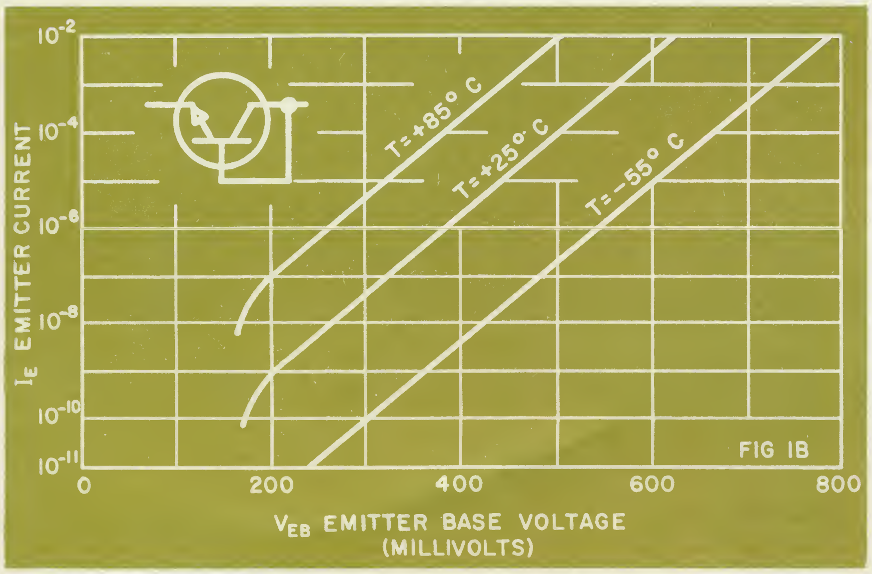

FIG 1B

When plotted on semilogarithmic coordinates, it can be seen that the emitter base voltage of a diode-connected silicon planar varies logarithmically with current at any one temperature, changing about 60 millivolts per decade of current ratio at 25°C. There is also a temperature dependence of approximately 2 millivolts per °C in the mid-range of currents. The logarithmic conformity for low currents is better at low temperatures than at high temperatures (attributable to increasing leakage with temperature). Although not readily apparent by casual inspection, the slopes of the straight-line portions of the curves exhibit a temperature variation, being slightly steeper at higher temperatures.

As shown in figure 2a, an operational amplifier is a convenient means of utilizing the characteristics of a logarithmic junction element. It provides excellent input and output isolation because the junction (feedback) current is essentially the input signal current (if the current offset is low) and is independent of loading. Furthermore, since the input is held at virtual ground potential by the inverse feedback, low signal voltages (millivolts) in series with an input resistor may be used, although the junction voltage drop may be a large fraction of a volt.

In order to expand the range of logarithmic variation for display on an indicating meter the scheme shown in figure 2b might be employed. This method is extremely temperature sensitive. A much better scheme is that of 2c in which a similar logarithmic transistor is used as a temperature compensator. For good accuracy the indicating meter should have a full scale current considerably less than the compensating junction reference current I_E.

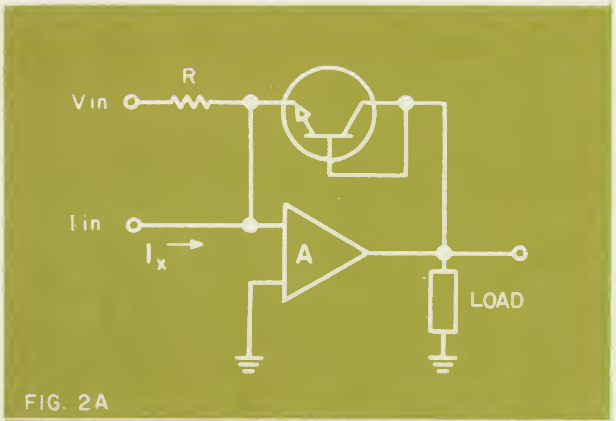

FIG. 2A

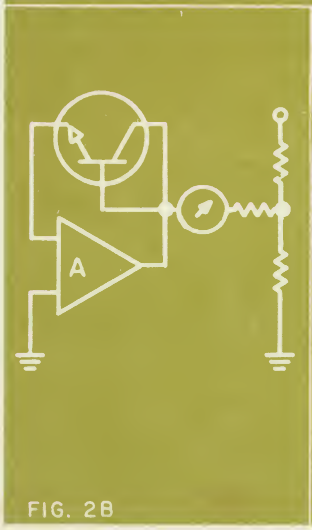

FIG. 2B

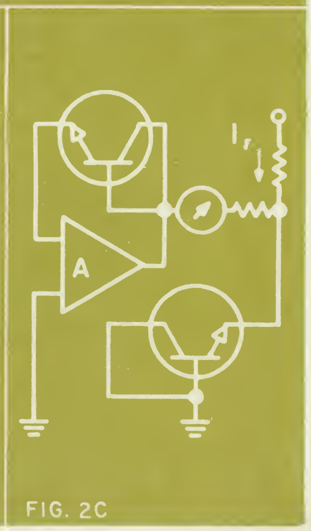

FIG. 2C

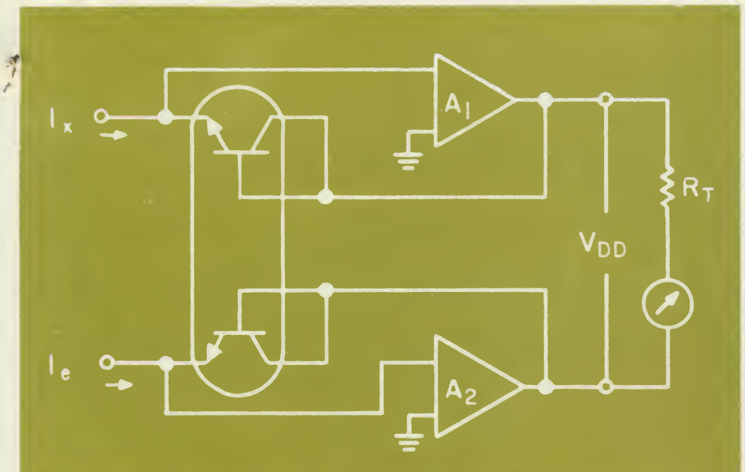

FIG 3

A much more powerful method than the above is shown in figure 3. By using a second operational amplifier with the reference transistor, the magnitude of the reference current is freed from any restrictions imposed by the indicating meter, and the difference signal V_{DD} across the amplifier outputs is proportional to the ratio between signal currents I_X and I_R. A well-matched transistor pair assembly minimizes drift. There is also the possibility of compensating for logarithmic slope temperature coefficient by employing a positive temperature series resistor R_T.

The three-amplifier method of figure 4. Extends the usefulness of the logarithmic ratiometer circuit. Here the third amplifier is employed as a subtractor to convert the differential signal to a signal which is referenced to ground. The subtractor should be separately trimmed for best common mode rejection before connecting to the outputs of A_1 and A_2. If $R_1 = R_3$ and $R_2 = R_{4a} + R_{4b}$ the logarithmic slope of about 60 millivolts per decade will be amplified by the ratio $\frac{R_2}{R_1}$.

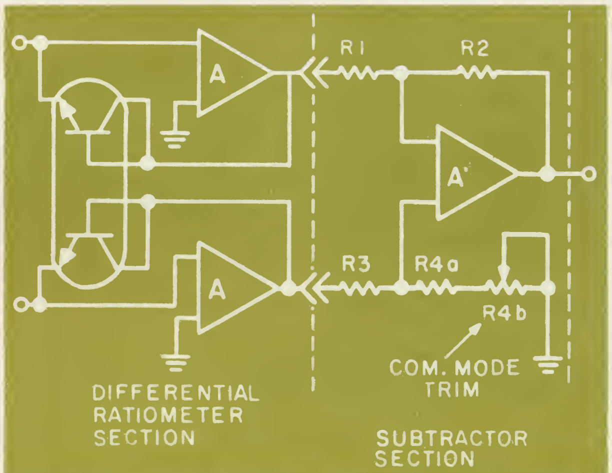

FIG. 4

If it is necessary to provide a readily adjustable gain, the four amplifier scheme shown in figure 5. is considerably more convenient than the three amplifier method, since it avoids the necessity for adjusting two resistors together with the accuracy required for maintaining optimum common-mode rejection in the subtractor. There is also the possibility of using a positive T.C. resistor for R_5 to correct for logarithmic slope change with temperature. For best operation at low current levels, input amplifiers A_1 and A_2 should be low offset current types such as Nexus type CDA-3. Amplifiers A_3 and A_4 may be any good general-purpose differential operational amplifiers such as Nexus type DA-1, SA-1, etc.

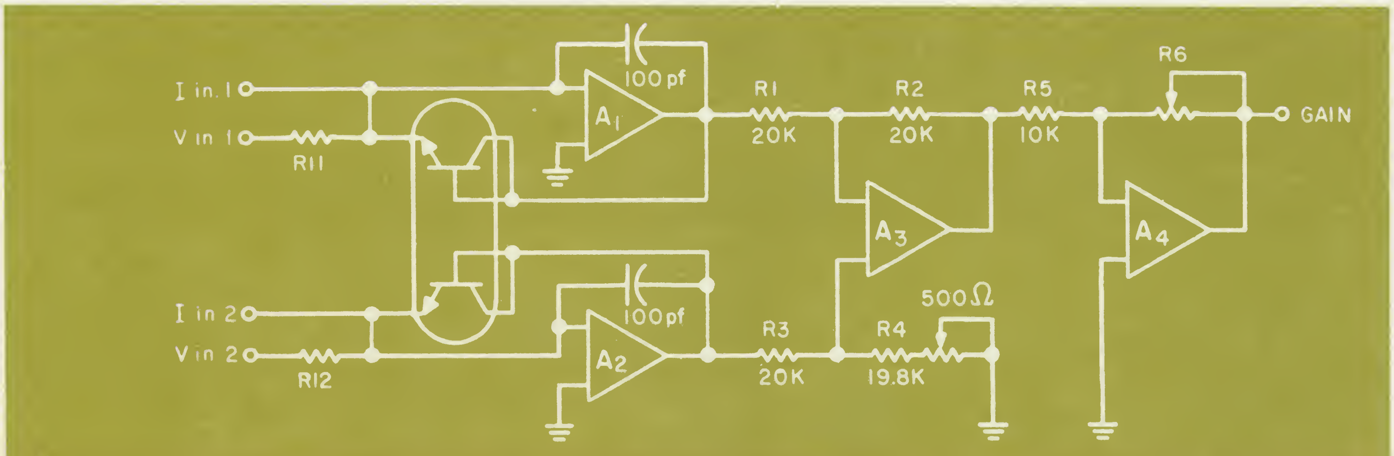

FIG 5

FOR FURTHER INFORMATION CONTACT NEXUS RESEARCH LABORATORIES INC.

APPLICATIONS

I. The logarithmic ratiometer may be used as a wide-range current or voltage meter by supplying a fixed reference current into one input (as mentioned previously). Figure 6 shows the scale of a logarithmic multimeter suitable as a general purpose laboratory instrument for measuring voltages, currents, resistances, conductances, etc. The 4-decade scale minimizes the need for range switching and is very useful for rapid trouble-shooting when using the logarithmic multimeter as a servicing test instrument.

FIG. 6

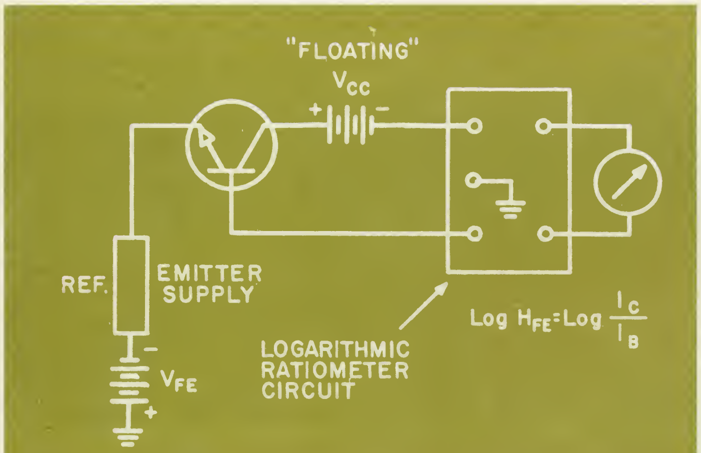

FIG. 7

II. An interesting application of a logarithmic ratiometer is in direct measurement of d-c current gain H_{FE} of junction transistors. Since H_{FE} is defined as the ratio I_C/I_B, it is simple matter to construct a direct reading H_{FE} meter with a logarithmic scale. Figure 7 shows a typical circuit used for measuring H_{FE} of NPN transistors. (Modification for PNP transistors is obvious and need not be shown.)

III. Another application, as a comparator for tracking of non-linear conductances, is shown in Figure 8. Here the test voltage e_g is swept over the desired range, and tracking of devices (conductances) under test is exhibited as a constant output from the logarithmic ratiometer.

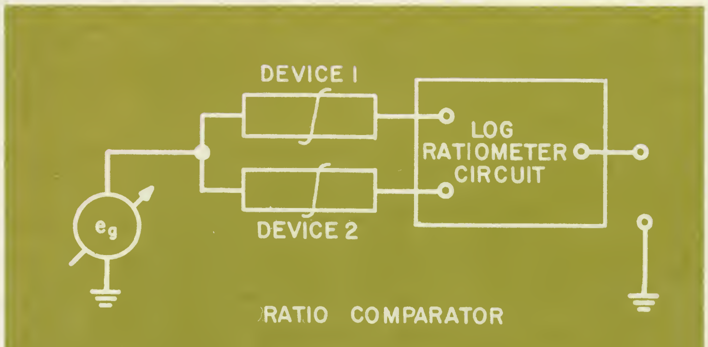

FIG. 8

Choice of operational amplifier type depends on minimum signal current range. The following types are suggested:

Signal Current Range	# of Decades	NEXUS Amplifier Type
10^{-8} to 10^{-2}	6	CDA-3a, CLA-3
10^{-7} to 10^{-2}	5	CDA-12a, SA-2
10^{-6} to 10^{-2}	4	DA-1a, SA-1

Matched transistor pairs, encapsulated in high thermal conductivity plastic, and tested for logarithmic conformity are available from NEXUS.

NEXUS
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PRICE LIST:

FEBRUARY 1, 1964

SUPERSEDES ALL EARLIER PUBLISHED PRICES

PREFERRED TYPES

SOLID-STATE OPERATIONAL AMPLIFIERS AND RELATED MODULES

TYPE	DESIGNATION	PRICE EACH BY QUANTITY 1 to 4	5 to 9	10 to 24	25 to 49	50 to 99	100 to 249	MATING SOCKET
PREMIUM -LINE- ALL SILICON	DA-1a	$ 85	$ 82	$ 79	$ 76	$ 73	$ 70	NSK-1
	LA-1	75	73	72	71	69	67	NSK-3
	CDA-3a	160	156	152	148	144	140	NSK-1
	CLA-3	155	151	147	143	139	135	NSK-3
	CDA-12a	135	132	129	126	123	120	NSK-1
	CLA-12	125	122	119	117	115	112	NSK-3
	DL-1	125	122	119	117	115	112	NSK-3
	FSL-12	175	169	167	162	159	155	NSK-3
ECONOMY -LINE- ALL SILICON	SA-1	49	47	45	43	41	39	NSK-3
	SA-2	65	63	61	59	57	55	NSK-3
	SL-6	85	82	79	76	73	70	NSK-3
	FSL-6	99	95	92	88	84	80	NSK-3
SI-GE HYBRID	SGX-3	40	40	40	40	37	35	NSK-3
BOOSTER -AMPLIFIER- ALL SILICON	BA-50	55	50	48	46	44	42	NSK-2
	BA-50L	55	50	48	46	44	42	NSK-3
	BA-100	110	QUANTITY PRICES GIVEN ON INQUIRY					NSK-3
	BHV-510	125						--
VOLTAGE REGULATOR -AMPLIFIER- ALL SILICON	PRR-1	55	53	51	47	44	42	NSK-2
	PRS-1	50	48	46	44	42	40	NSK-2
	NRR-1	85	83	81	78	74	70	NSK-2
	NRS-1	80	78	76	74	71	67	NSK-2

POWER SUPPLIES, SOCKETS, AND ACCESSORIES

POWER SUPPLIES	NPS-1	195	WRITE FOR QUANTITY PRICES					
	NPS-2	195						
AMPLIFIER SOCKETS	NSK-1	6.50	6.25	5.85	5.60	5.40	5.20	
	NSK-2	6.50	6.25	5.85	5.60	5.40	5.20	
	NSK-3	3.00	2.85	2.70	2.60	2.50	2.40	
	MSQ	2.50	2.35	2.25	2.15	2.05	2.00	
UNIVERSAL TEST-SOCKET PLUG BOARD	PGB-1	7.50	7.10	6.75	6.40	6.20	6.00	
MATING RECEPTACLE	R-612	1.75	1.75	1.75	1.75	1.75	1.75	When Ordered With PGB-1
VECTOR CUP RECEPTACLES	RS-23	1.00 PER SET OF 8						
	RS-24							
ALUMINUM SHIELD MODULE RETAINERS	ALS-1	3.00	2.85	2.70	2.60	2.50	2.40	
	ADS-1	3.00	2.85	2.85	2.60	2.50	2.40	

TERMS - 1% - 10 DAYS; NET - 30 DAYS ------MINIMUM ORDER $10.00

SEE REVERSE OF SHEET FOR PRICES OF OTHER NEXUS AMPLIFIER TYPES, AND SUBSTITUTION CHART.

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OTHER STANDARD AND REPLACEMENT TYPES

TYPE	LIST PRICE	REMARKS	PREFERRED TYPE REPLACEMENT
DA-21	$160	±20 Volt Output otherwise similar to DA-1a	
DL-21	185	±20 Volt Output otherwise similar to DL-1	
CDA-22	225	±20 Volt Output otherwise similar to CDA-12	
MCA-1	195	Subminiature General Purpose Amplifier	
MCA-2	220	Subminiature General Purpose Amplifier	
SS-1	75	General Purpose All Silicon	LA-1
SS-2	95	General Purpose All Silicon, Lower I_{os}	CLA-12
SS-3	155	General Purpose All Silicon, Very Low I_{os}	CLA-3
SS-12	125	General Purpose All Silicon, High Gain	CLA-12
SGX-4	60	Si-Ge Hybrid High Gain	SA-2
SGX-23	50	Si-Ge Hybrid ±20V Out Discontinued Type	-
SGX-24	70	Si-Ge Hybrid ±20V Out Discontinued Type	-
SGL-5	60	Si-Ge - Hybrid	SL-6
SGL-6	80	Si-Ge - Hybrid	SL-6
FA-1	105	Fast Feedback Amplifier, All Silicon	-
AA-11	85	General Purpose All Silicon	DA-1a
DA-11	95	General Purpose All Silicon	DA-1a
DA-2	125	General Purpose All Silicon	CDA-12a
CDA-2	160	General Purpose All Silicon, High Gain	CDA-12a
CDA-33	175	General Purpose All Silicon, Low I_{os}	CDA-3a
SG-1	62	Si-Ge Hybrid General Purpose	SA-1
SG-2	85	Si-Ge Hybrid General Purpose	SA-2
SG-11	49	Si-Ge Hyrbid General Purpose	SA-1

For operational amplifiers with special characteristics, or in special packages, or for instrumentation packages involving the use of operational amplifiers, your inquiry directed to NEXUS' applications engineering department will receive prompt attention.